- Provide enough funds to buy adequate weapons for testing, a continuing problem according to reports by GAO and the DoD Inspector General.[3]

- Ensure that all operational tests are made on weapons representative of those that will actually be produced for use by operating units, and, particularly during later operational tests, ensure that actual production versions are used in testing.

- Ensure that targets simulating enemy forces represent the threat realistically. The DoD Inspector General found this not to be the case in some recent tests, such as those of the new Aegis antimissile system.[4] Ranges over which a system is tested must also be realistic, a problem in recent testing of the air-launched cruise missile.[5]

- Ensure that test facilities are available in a timely manner. In concurrent programs in particular, testing delays can wreak havoc in an already compressed schedule.

As with all actions in the complex arena of defense procurement, efforts to ensure adequate tests entail potential problems. Program costs could increase if adequate provisions have not been made for testing during initial program planning. Difficult choices may have to be made if required testing facilities are not available.

ENSURING ADEQUATE RISK ANALYSIS

Among the most important factors to consider in allocating resources for any weapons system is the risk that the program will not achieve its planned goals. Contributing to this risk are the chances of major

3. General Accounting Office, ibid., and Senate Committee on Government Affairs, *Hearings on the Management of the DoD*, 98:1 (June 23, 1983), Part 5, p. 21.

4. Senate Committee on Government Affairs, *Hearings on the Management of the DoD*, 98:1 (June 23, 1983), Part 5, p. 55.

5. Ibid., p. 19.

cost increases, delays in schedule, or performance that falls below planned levels. Any of these could have a serious effect on military capability.

DoD regulations encourage, but do not require, an assessment of risk. Evidence suggests that risk analysis is not widely used. None of the programs reviewed for this study provided a documented comprehensive risk analysis for the acquisition milestones. A GAO audit in 1986 found that only 12 of 48 program managers who were queried indicated that a formal, quantitative measure of program risk had been used in preparing their programs' budgets.[6] Even when systematic assessments of risk are performed, they are not made available to the Congress. For example, no such assessments appear in the Selected Acquisition Reports that are sent to the Congress regarding major weapons systems. (Appendix B discusses more fully DoD's risk analysis policies and their implementation.)

The Congress may wish to require a comprehensive, systematic risk assessment for selected major programs. Since such assessments would involve considerable effort, they could be limited to key programs, perhaps focusing on those that have substantial concurrency.

Identifying Risks

In reviewing any risk assessment, it is necessary to be sure that all major sources of potential risk have been considered. Table 3 shows six key sources of risk and the factors to consider in assessing the importance of each.

For example, an important source of risk is the potential for changes in the enemy threat. During the development and production of a weapons system, which may take 10 years or more, the enemy may acquire new technology; other changes may occur in the scope or characteristics of the threat. Any change in the threat may substantially affect the program's cost, schedule, and performance. Assessing this sort of risk is difficult, since it requires examining the historical experience of requirements for similar types of weapons, the degree of

6. General Accounting Office, "Status of the Defense Acquisition Improvement Program's 33 Initiatives" (September 1986), p. 17.

confidence one can have in threat assessment projections, and the possibilities for alternative technical or policy solutions.

Techniques for Analyzing Risk

Once the main sources of risk have been identified, various analytic techniques can be used to quantify them. Several of these techniques focus on the risks of increased costs or delayed schedules. The Program Evaluation and Review Technique (PERT) identifies key deci-

TABLE 3. MAJOR RISK FACTORS IN CONCURRENT WEAPONS SYSTEMS ACQUISITION

Source of Risk	Factors to Consider in Assessing Risk
Change in Enemy Threat	Historical experience with similar system Experts' confidence in their threat assessments Possibility of need for new weapon design
Type of Contract	Fixed price for highly technical systems inherently risky
Manner of Funding	Likely variation from planned funding (because of budgetary constraint or unanticipated inflation)
Technical Elements	Level of technology being attempted Feasibility of implementing system design concepts
Weapons Testing	Availability of adequate test assets, including facilities
Transition to Production	Feasibility of planned manufacturing process Lead time for materials, special tooling, labor

SOURCE: Congressional Budget Office.

sion points that are critical to program completion. Regression analysis can be used to predict costs based on experience with historical systems that have similar characteristics such as weight, speed, and range.

Other techniques have more general application. Decision analysis, for example, identifies important decisions and assigns the probabilities of various outcomes. It could be used to assess cost and schedule risks as well as the risk of technical problems arising that might prevent the system from meeting its performance goals. The Delphi methodology used in marketing analysis can also be used to assess systematically a range of expert opinion bearing on any type of risk.

APPENDIXES

APPENDIX A

CURRENT LEGISLATION, POLICIES, AND REGULATIONS AFFECTING CONCURRENCY

Existing laws and federal regulations, including Defense Department and service regulations and instructions, permit concurrent development and production of weapons systems. Recent legislation and changes in DoD acquisition policies, however, have placed certain constraints on the acquisition process to reduce the risks associated with concurrency. The following discussion summarizes the relevant recent legislation and outlines current defense acquisition policies that could affect the use of concurrency.

LEGISLATION AND GOVERNMENTWIDE REGULATIONS

In recent years, the Congress has acted to constrain the risks of concurrency by placing increased emphasis on operational testing of weapons systems. In 1983, the Congress established an independent office of Operational Testing and Evaluation (OT&E) to advise the Secretary of Defense on operational testing matters and to report to the Congress concerning operational testing of major weapons systems. Chapter 4 of Title 10 of the United States Code requires that, before beginning full-rate production of a major weapons system, the Director of the office must report to the Congress concerning the adequacy of the system's OT&E. The Director must also assure the Congress that the items or components that were tested are effective and suitable for combat.[1] Such assurances should minimize the risk of having to make costly alterations in weapons systems after full-rate production has begun.

Several provisions in the 1987 Defense Authorization Act are also intended to reduce the risks of concurrency. Section 909, for example,

1. Senate Armed Services Committee, *National Defense Authorization Act for Fiscal Year 1984*, Report No. 98-213, 98:1 (1983), pp. 74-76.

requires that, unless the Congress grants a waiver, the DoD must develop and test competitive prototypes of major weapons systems under realistic conditions before awarding a production contract. This provision reflects the Congress's belief that competition between prototypes will provide an incentive to contractors to improve system performance beyond levels that could be expected in a sole-source contracting environment. Such competition, together with the requirement for realistic testing, should reduce the risk that production models may need expensive retrofits or changes.

Chapter 139 of Title 10, United States Code, specifies that testing of the survivability and lethality of a weapons system must be satisfactorily completed before a program may begin full-rate production. In addition, the legislation states that "a major defense acquisition program may not proceed beyond low-rate initial production until initial OT&E of the program is completed."[2] The successful completion of survivability, lethality, and initial OT&E before beginning full-rate production should also reduce the risk that major retrofits will be needed.

Aside from these legislative constraints affecting concurrency, current governmentwide acquisition regulations neither prohibit the use of concurrency nor provide detailed guidance concerning its use. The basic federal instruction on major system acquisition policy (OMB Circular A-109), for example, states that limited production of a system may begin when a system's design concept has been satisfactorily demonstrated. Full production, the instruction continues, can begin when the "mission need and program objectives are reaffirmed and when system performance has been satisfactorily tested . . . and evaluated in an environment that assures demonstration in expected operational conditions."[3] In either case, the meaning of "satisfactory" is not specified. Consequently, considerable latitude exists for program planners and managers regarding the extent to which concurrency can or should be used.

2. House Armed Services Committee, *National Defense Authorization Act for Fiscal Year 1987*, Report No. 99- 1001, 99:2 (1986), pp. 111-113.

3. Office of Management and Budget, "Major Systems Acquisition - Circular A-109," April 1976, p. 10.

The Federal Acquisition Regulations (FAR) also fail to provide specific guidance on when to use concurrency. In its discussion of acquisition planning, the FAR simply requires that "if concurrency of development and production is planned" the agency should "discuss its effects on cost and schedule risks." Concerning testing, the FAR requires a discussion of the "extent of testing to be accomplished before production release."[4]

DOD POLICIES AND REGULATIONS

The basic acquisition regulations of the Department of Defense emphasize the need to reduce the length of the acquisition process. Department of Defense Directive 5000.1, for example, states that "a primary goal in developing an acquisition strategy is to minimize the time it takes to satisfy the identified need consistent with common sense, sound business practices, and the basic management policies of this Directive."[5] Service regulations also refer specifically to the need for reducing acquisition time.[6] Both DoD and service regulations permit the use of concurrency as a means to achieve this goal.

DoD's basic acquisition regulations provide service and program planners with considerable flexibility in using concurrency. DoD Directive 5000.1, for example, directs the services, "commensurate with risk," to reduce lead time through concurrency, and to combine acquisition phases and development and operational testing "when appropriate."[7] Additional flexibility exists since few prerequisites for production are specified. DoD Instruction 5000.2, for example, lists program areas to be considered by the Defense Acquisition Board (DAB) before the approval of production, but does not identify specific

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4. Federal Acquisition Regulations, Subparts 7-1 and 7-2.

5. Department of Defense Directive 5000.1, "Major and Non-Major Defense Acquisition Programs," September 1, 1987, p. 5.

6. Army Regulation 70-1, "System Acquisition Policy and Procedures," November 12, 1986, p. 3; and OPNAV Instruction 5000.42C, "Research, Development and Acquisition Procedures," May 10, 1986. p. 4.

7. Department of Defense Directive 5000.1, p. 5.

requirements within these areas.[8] The instruction does require, however, that adequate testing and "operational effectiveness and suitability" be accomplished before beginning full-rate production. "Adequacy," "effectiveness," and "suitability" are not defined, however.[9]

Although DoD acquisition policy regulations encourage the use of concurrency "commensurate with risk," they also contain provisions that endorse using a sequential acquisition approach. For instance, they encourage the use of competitive prototyping before beginning production and early OT&E.[10]

The basic DoD regulation concerning testing and evaluation, DoD Directive 5000.3, endorses reducing acquisition time by combining development and operational testing. According to the directive, combined testing "may be used when cost and time benefits are significant . . . provided that test objectives are not compromised."[11] Combined testing is characteristic of concurrent programs in that it can be a primary means to reduce acquisition time and accelerate a production decision.

On the other hand, DoD Instruction 5000.3 also contains guidance supporting sequential acquisition. For example, the directive requires that, before a Milestone III production decision, testing results must confirm that all significant design problems have been identified; that solutions are available; and that items tested are "effective and suitable for their intended use."[12] The directive also states that, before a production decision, operational testing must be completed on a representative item for production and must "ensure that it meets required operational thresholds."[13] An important ambiguity exists, however, since the directive does not distinguish between testing prerequisites for an initial, low-rate production decision (Milestone IIIa) and a full-

8. Department of Defense Instruction 5000.2, "Defense Acquisition Program Procedures," September 1, 1987, p. 4.

9. Department of Defense Directive 5000.3, "Test and Evaluation," March 12, 1986, p. 7.

10. Department of Defense Directive 5000.1, p. 6.

11. Department of Defense Directive 5000.3, p. 8.

12. Ibid., p. 7.

13. Ibid.

rate production decision (Milestone IIIb). If the above prerequisites apply only to a full-rate production decision, they do not constrain the use of concurrency vis-a-vis an initial production decision.

APPENDIX B

RISK ANALYSIS POLICIES AND THEIR IMPLEMENTATION

In general, government and Department of Defense policies support, but do not require, the use of a comprehensive, formal risk analysis of major weapons programs as part of the acquisition and budget processes. The federal government's basic acquisition policy guidance, for example, encourages, but does not require, agencies to include "methods for analyzing and evaluating contractor and Government risks" in developing acquisition strategies for major systems.[1] The government's basic acquisition regulations, including the Federal Acquisition Regulations (FAR) and the DoD Supplement to the FAR, do not require the use of risk analysis for major procurement programs.

Corresponding acquisition regulations for the DoD also encourage, but do not require, the use of risk analysis for acquisition milestone or annual budget reviews. For example, DoD Directive 5000.1, "Major and Non-Major Defense Acquisition Programs," encourages program managers to "consider" conducting studies to assess technological risk and to develop alternatives for high-risk areas.[2] Further, DoD Instruction 5000.2 indicates only that the senior DoD acquisition review board, the Defense Acquisition Board (DAB), may "consider" whether a procurement strategy is appropriate to program cost and risk assessments.[3]

The latter instruction, it should be noted, requires that key areas of technological and producibility risk be identified in a System Concept Paper for review by the DAB at Milestone I (System Concept Demonstration and Validation) and that test and evaluation results concerning risk areas be reported in the Decision Coordinating Paper

1. Office of Management and Budget, "Major System Acquisitions Circular A-109," April 5, 1976, p. 5.

2. Department of Defense Directive 5000.1, "Major and Non-Major Defense Acquisition Programs," September 1, 1987, p. 5.

3. Department of Defense Instruction 5000.2, "Defense Acquisition Program Procedures," September 1, 1987, p. 5.

at Milestone II (Full-Scale Development).[4] The DoD Instruction 5000.2 does not, however, specify that risk analysis be used to fulfill these requirements.

The DoD also requires that the DoD Product Engineering Services Office (DPESO) conduct an assessment of production readiness before a commitment to produce a weapons system, and that DPESO "identify potential problem areas which constitute production, cost, or schedule risks." The DoD directive concerning production readiness reviews also states, "Each risk will be expressed in terms of its relative magnitude and potential consequences."[5] The instruction does not provide specific guidance, however, concerning the methodology used to determine the magnitude and consequences of producibility risks.

The DoD Instruction 7041.3 concerning economic and program evaluation methods for resource management requires that risk assessments be made for major programs, but does not direct that formal risk analysis methods be used. The directive states that "special degrees of risk/uncertainty associated with a particular program/project, may be pointed out quantitatively in an analysis and used for program review purposes."[6] The directive also requires that program schedules and funding should be structured to accommodate program uncertainties, but does not require that such uncertainties be measured and identified separately.[7]

Service regulations and guidance also support, but do not require, the use of formal risk analysis to support program and budget reviews for major programs. Army Regulation 70-1, for example, states that development and procurement programs may be funded, "if appropriate," using a risk analysis method called Total Risk Assessing Cost

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4. Ibid., p. 4-2.

5. Department of Defense Instruction 5000.38, "Production Readiness Reviews," January 24, 1979, p. 3.

6. Department of Defense Instruction 7041.3, "Economic Analysis and Program Evaluation for Resource Management," October 19, 1972.

7. Ibid.

Estimate (TRACE).[8] (The TRACE method uses a risk factor approach to risk analysis.) The Navy requires that programs must "include efforts to identify, control, and reduce program risk," but does not specify the use of risk analysis to support program and budget reviews.[9]

Both through legislation and through management reforms, the Congress and the DoD have initiated a number of measures to reduce program risks. Requirements now exist for using performance warranties for major weapons systems; for reporting on operational testing results before approval for full-rate production; for using independent cost estimates; for developing and testing prototypes of systems and subsystems; and for using lower-risk, more gradual approaches to weapons system development (Pre-Planned Product Improvement). The services are permitted to budget for program risks through funding for anticipated program changes (Engineering Change Orders) or management reserves.[10] Little, however, has been accomplished in carrying out measures designed to ensure that program risk is identified, measured, and analyzed in a systematic way to support other risk-reducing policies.

Past attempts by the DoD to require risk analysis have achieved only limited success. In 1981, for example, the DoD undertook a management initiative to budget for technological risk as one of 32 ways to improve defense acquisition (the "Carlucci Initiatives"). Under this initiative, the Deputy Secretary of Defense emphasized the need for the services to evaluate, quantify, plan, and budget for program risk. He requested the Navy and Air Force to review the Army's TRACE program and "either adopt it or propose an alternative . . . ."[11] None of the other services subsequently adopted the TRACE program as a budgeting requirement. Moreover, the Army currently applies TRACE only to a limited number of its programs.

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8. Department of the Army, Regulation 70-1, "System Acquisition Policy and Procedure," November 12, 1986, p. 16.

9. OPNAV Instruction 5000.42G, "Research, Development, and Acquisition Procedures," May 10, 1986, p. 3.

10. See General Accounting Office, "Defense Budget--Contingency Funds in Three Aircraft Procurement Programs," October 1987.

11. Deputy Secretary of Defense Memorandum, "Improving the Acquisition Process," April 30, 1981, p. 12.

Despite DoD's policies, initiatives, and regulations supporting the use of risk analysis, indications (such as the limited application of TRACE) are that it is used only occasionally, or at least that it is not reported or reviewed at higher levels of management in the DoD. According to a recent GAO audit of DoD's implementation of the "Carlucci Initiatives," only 12 of 48 program managers who were queried indicated that a formal, quantitative measure of program risk had been used to derive their program budgets.[12] Another GAO review of DoD's risk assessment efforts observed that, although qualitative assessments of risk were usually made at acquisition milestones, none of the acquisition milestone documentation reviewed for 25 major weapons systems contained any quantitative analysis of program risk.[13] Program milestone documentation for the weapons systems examined for concurrency in Chapter II confirmed GAO's findings; qualitative assessments were made for some, but no quantitative risk analysis was cited.

Currently, the Congress is not informed about program risk based on risk analysis conducted by the Department of Defense. Program and budget documentation provided by the DoD to the Congress, such as the SARs and the Congressional Data Sheets, do not contain data based on risk analysis. In the past, the DoD has suggested that providing information on program risk to the Congress would result in disapproval for any funds requested to cover risk.[14]

12. General Accounting Office, "Status of the Defense Acquisition Improvement Program's 33 Initiatives" (September 1986), p. 17.

13. General Accounting Office, "Technical Risk Assessment: The Status of Current DoD Efforts" (April 1986), p. 49.

14. Deputy Secretary of Defense Memorandum, "Improving the Acquisition Process," April 30, 1981, p. 12.

GLOSSARY

Bradley Fighting Vehicle. The Army's light armored fighting vehicle that can be used to transport troops on the battlefield (the Infantry Fighting Vehicle--IFV), and also for scouting, reconnaissance, and security missions (the Cavalry Fighting Vehicle--CFV). It is armed with a 25mm automatic cannon that can be fired on the move, and also carries the TOW antitank guided missile system. The Bradley entered full-scale development in June 1976, was approved for production in January 1980, and achieved initial operational capability (IOC) in December 1983.

CH-47 Helicopter. A medium-lift helicopter used by the Army and the Marine Corps to move troops, ammunition, repair parts, petroleum, artillery, and other weapons. A modernization program was initiated in October 1975 to improve the helicopter's performance capabilities. Initial production of the modernized CH-47 was authorized by the Army in August 1980, and IOC occurred in February 1984.

CH-53 Helicopter. Used by the Navy and Marine Corps to perform heavy lift operations including transporting equipment, supporting construction, removing damaged aircraft from carrier decks, and providing an airborne mine countermeasure capability. The CH-53 entered full-scale development in May 1975, was authorized for production in January 1978, and reached IOC in June 1982.

Copperhead Artillery Projectile. A cannon-launched 155mm laser-guided projectile used by the Army and the Marine Corps against armored vehicles or hardened targets. The Copperhead was approved for full-scale development in June 1975, was authorized for production in February 1979, and became operational in December 1982.

F/A-18 Aircraft. The Navy's newest fighter aircraft, designed primarily for air-to-air combat. It can also perform light attack, reconnaissance, and training missions. Full-scale development of the

F/A-18 was authorized in December 1975, production was approved in June 1981, and IOC was achieved in March 1983.

Harpoon Missile. The Navy's tactical radar-guided missile designed for use against surface naval targets and launched from aircraft, surface ships, or submarines. Harpoon entered full-scale development in June 1973, was approved for production in June 1975, and achieved IOC in July 1977.

Hellfire Missile. A tactical air-to-surface missile used by the Army and the Marine Corps that is guided by a laser designator and employed against armored targets. The Hellfire missile entered full-scale development in February 1976, was approved for production in November 1981, and achieved IOC in July 1986.

Imaging Infrared (I2R) Maverick Missile. A tactical air-to-surface missile developed by the Air Force to locate and strike ground targets including armored vehicles, fortifications, gun positions, communication centers, and aircraft shelters. The I2R Maverick entered full-scale development in September 1976, was approved for production in September 1982, and became operational in February 1986.

M1 Tank. The Army's primary main battle tank, armed with a 105mm gun and capable of traveling 45 miles per hour. The tank has a fire control system that permits daytime or nighttime operation, and can fire at armored or unprotected targets while on the move. The M1 began full-scale development in November 1976, was approved for production in April 1979, and achieved IOC in January 1981.

Patriot Missile. The Army's land-mobile air defense system, deployed in fire units consisting of a radar set, a control station, a power source, and eight launching stations armed with four missiles each. It is capable of intercepting high-performance aircraft at all altitudes. Patriot entered full-scale development in February 1972. A decision was made to restructure the program in 1974, and approval was given to resume engineering development in 1976. The missile was approved for production in September 1980, and was initially deployed in the United States in June 1983 and in Europe in March 1985.

Phalanx Gun System. The Mark 15 Phalanx (or Close-in Weapon System) is an automatic gun fire-control system used on surface ships to defend against antiship missiles. The system automatically searches for targets, evaluates and tracks the threat, and orders and adjusts firing of a Gatling-type gun. Phalanx was authorized for full-scale development in December 1972 and for production in September 1977, and its IOC occurred in February 1980.

SH-60B Helicopter. Also called LAMPS III--Light Airborne Multi-purpose System III. It is deployed on Navy surface ships to detect, identify, track, and interdict enemy surface vessels and submarines. LAMPS III is also used for search and rescue, supply replenishment, medical evacuation, and other fleet support missions. The SH-60B was authorized to begin full-scale development in February 1978, initial production was approved in November 1981, and IOC was achieved in July 1984.

Stinger Missile. A man-portable, infrared-seeking guided missile used by the Army and the Marine Corps against low-altitude, high-speed aircraft. The basic Stinger missile was approved for full-scale development in May 1972 and for production in November 1977, and was first deployed in February 1981.

UH-60 Black Hawk Helicopter. The Army's multipurpose helicopter capable of transporting troops, weapons, and supplies. It can also be used for air assault, rescue, and evacuation missions. The Black Hawk was approved for full-scale development in May 1971, authorized to begin production in November 1976, and achieved IOC in November 1979.